SHADES OF GRAY:

THE DIVERSE DYNASTY OF

SHALE, SLATE, AND SCHIST

Wine growers and wine lovers appear in awe of slate and schist, celebrating, comparing, and contrasting the wines grown on them. So why, asks **Alex Maltman**, does shale attract nothing like the same reverence, when the three rocks are so closely related and when they all come from the most common geological material on Earth: mud?

There's a funny thing in the wine world about shale. It's very fashionable these days in wine and vineyard descriptions to remark on the geology—but shale? It's seldom mentioned. How many vineyards can you name that are founded on shale, or producers who boast that their wines come from shaly soils? And yet shale is just about the most widespread bedrock on the Earth's land surface and must presumably, therefore, be pretty common in vineyards. It's as though the rock is of little viticultural relevance, or perhaps it just lacks, well, marketing charisma.

What a contrast with slate. This rock, despite having a much more restricted distribution, is eagerly talked about by wine people. In fact, where it does occur in vineyards, notably alongside some of the German rivers, it is treated almost with reverence; many believe it is the key to the distinctiveness of the wines produced there. Similarly, schist is not widespread, but for some growers it is celebrated and trumpeted as bringing a special quality to their wines. Schist is their touchstone. But shale? Perhaps the problem is its very ordinariness, rather like a sliced white bread of rocks!

In the world of wine we have three distinct rocks with differing auras. In geology, however, things are not like this at all. Geologically speaking, these three rocks are closely related, with shale blurring, in a kind of evolutionary sequence within the Earth, into slate, and slate in turn graduating into schist. In this article I will outline how this happens.

I wish also to bring out here another aspect of these three rock names. Each one, though a single word, in fact covers a considerable diversity of materials, spanning various chemical and physical properties and giving rise to wide assortments of vineyard soils. And we will see that while in wine marketing this seems irrelevant for shale, it leads to promotion strategies for wines from slate that are quite different to those from schist—none of which fits comfortably with the geology of the rocks.

The key to it all: mud

Any bare rock at the Earth's surface—be it a natural crag or cliff face, a tombstone or cathedral—is continually being attacked by the processes of weathering. Chemical reactions with the atmosphere convert some of the material to fine clay minerals, and at the same time the rock is being physically disintegrated into the loose detritus that geologists call sediment. Inevitably, this weathered debris will be moved away, downslope by gravity and across the ground by wind, running water, or even by moving ice. And all the time, the sediment grains will be banging into each other, abrading and shattering, and becoming smaller and smaller. It is the resulting fine material—silt and clay—that concerns us here.

This shifting fine sediment may accumulate temporarily in places such as a lake bottom or riverbed (or in a vineyard puddle!), but eventually most of it will reach the coast and ultimately be swirled out to sea, to settle slowly on the sea floor. We are talking here about the silt-clay mixture called mud—hardly glamorous stuff, but actually hugely important for life on Earth and, especially after it has been hardened into rock, a material that impinges on all kinds of human activities. In fact, the Geological Society in London designated 2015 as The Year of Mud. And it's tremendously widespread: If we include the ocean floor, it is the single most widely distributed geological material at the surface of the solid Earth. Moreover, geologically it is the parent of the three rocks we are considering here—shale, slate, and schist. First, then, we need to look a little more closely at how this sloppy mud is transformed into solid rock.

Looking at it very simply, it's like squeezing a lump of wet potter's clay between your hands. At first it's easy to squeeze out a bit of the moisture. The material then gets that little bit stiffer, because the tiny clay particles are being brought closer together and more efficiently packed, and as you squeeze more, it gets progressively more difficult to squeeze out the remaining water. The tightening continues, and the clay mass becomes quite tough. In nature, it's the weight of sediment being added above that does the squeezing, and with all the time available there, chemical bonds start to develop between the increasingly packed particles such that eventually the material becomes hard enough to be called a rock. It normally takes the accumulation of hundreds of meters or more of overlying sediment and the passage of at least thousands of years to achieve this fully in nature, and we end up with a material that is properly described as a mudstone. But there's a fascinating accompaniment to all this, which will take us to shale.

On shale and rock fissility

Imagine a leaf falling from a tree. It doesn't dive downward and land on edge, but it flutters, with a side-to-side motion, before coming to rest flat on the ground. Additional leaves stack up around it, making a pile with the leaves themselves lying roughly horizontal, parallel to the ground. Any intervening debris may make a thin layer, and overall this will also be arranged parallel to the ground. The thing is that the clay minerals in mud, though tiny, have a distinctly flaky, leaf-like shape, so they settle in an analogous way on the seabed. Their parallel alignment will become enhanced as the mud is buried and progressively squeezed from above. There may occasionally be influxes of slightly coarser silt, perhaps due to a recent rainstorm on land, and this will be deposited in thin layers, across the sea floor.

Thus, in these various ways, the body of accumulating muddy sediment takes on a planar aspect: horizontal, parallel to the sea bottom. The layers of differing sediment are known by geologists as bedding, and with time the whole mass becomes hardened into a sedimentary rock.

If, at some later time, Earth's internal processes force this buried rock upward, then, coupled with the erosion inevitably taking place at the surface, the rock could be exposed for us to see, and even to floor a vineyard! And because of its internal structure, the clayey parts will have a tendency to break in a direction overall parallel to bedding—and this is the characteristic of shale. It's a rock hardened from sediment with most of the constituent particles too fine for us to see and, with a tendency to part in rough pieces overall parallel to bedding, the original horizontal of the sea floor. Geologists call this splintering a "fissility." The rock may have undergone some tilting during its uplift so that the fissility is no longer horizontal, but always, if it's to be called shale, it will roughly follow bedding. So, fissility in a rock is parallel to bedding, and shale is defined by its fissility. And it is this breakage parallel to bedding that is the key difference—as we shall see shortly—from slate.

Shale readily fractures into a splintery scree, which can be quite eye-catching. Consequently, the names of topographic features sometimes involve shale, such as Shale Ridge, Shale Peak, and Shale Hill, and names like these have found their way into winery names. Otherwise, the only mention that shale seems to get in wine literature is a casual comment about shaly vineyard soils, usually without much elaboration of why this might matter. Almost certainly, its chief relevance is to do with drainage, or the lack of it, though the behavior of disintegrated shale is complicated. On the one hand, a rubble of angular shale fragments will give a very well-drained soil, with all that means for vine growth. But in contrast, as the shale pieces weather down they will increasingly yield their constituent clay minerals, with an overall tendency to clog the soil pores and shut down the drainage. Also, shale comes in different colors, which may in more marginal areas of grape ripening have some thermal effect.

The rock shale, then, is defined by its physical characteristics, which means it can be of any chemical/mineral composition. The weathered rock that started it all could have been anything: The fragments it yielded could have diverse chemistries, the clay minerals could be rich in potassium, say, or calcium, manganese, zinc, or whatever. For instance, some shales in the Heiligenstein, of Kamptal, Austria, and the Mayacamas Mountains between the Napa and Sonoma Valleys, originated from volcanic parents and are rich in iron and magnesium; while around the Finger Lakes of New York and to the west side of Paso Robles, California, there are shales containing carbonate. That said, most shales are dominated by aluminum-bearing clay minerals and consequently, without much carbonate around, yield soils that are quite acid.

Now, suppose the shale that formed beneath the sea floor, as discussed above, isn't uplifted and exhumed but continues to be buried, as more sediment accumulates above it? Well, because temperatures increase downward into the Earth—as a trip down a deep mine testifies—the ambient temperature will be a little greater and, coupled with the additional sediment load, further burial prompts the atoms in the clay minerals to start to rearrange themselves and gradually attain configurations that are more stable in these new conditions. New minerals result, but just like the precursor clays they are distinctly platy in shape. And more than likely, at the same time another very intriguing effect will be arising.

At these burial depths, a few kilometers below the ground, the rock will be feeling the stresses that operate within our internally mobile planet, and these will be forcing the newly forming platy minerals to become aligned. In general, this new alignment will be at right angles to the impinging stresses, and it won't be parallel to the bedding. To visualize this, let's return to our pile of leaves that settled on the ground surface. If we scoop them up and squeeze them between our arms, there will be an overall tendency for each leaf to rotate, to flip so that it's now at right angles to our squeezing. The orientation of the new alignment depends entirely on how we squeeze the mass and has nothing to do with the ground, the horizontal, with how the leaves were arranged before. In other words, our buried shaly rock mass is starting to take on a new planar element due to these aligned new platy minerals, and its orientation is unrelated to the fissility. We are here entering the realm of slate.

Source of some great wines and a million roofs: slate

If this underground material in its early stages of a new mineral alignment were to be exhumed, we would find that it showed some tendency to break in this new direction but perhaps also, to some extent, along what remains of the shale fissility. The fragments, having broken off in two uneven directions, will be roughly batten shaped; such a rock is termed by geologists a pencil slate. It's not an important rock for us here, but it illustrates the point that shale graduates into true slate (which breaks cleanly into distinct sheets).

Thus there is no defined boundary between shale and slate. This is why reports on a particular vineyard area might seem a bit confused if the slates have only reached an early stage of development. It is why some reports on vineyards in the Rheingau, for example, say they have shale soils, while other literature declares that they are on slate. Neither is wrong. The middle Mosel provides a similar example in that it is a classic area of slate quarrying and of famously slaty vineyards, yet the bedrock has not changed greatly because some examples are celebrated for their beautiful and delicately preserved fossils. Normally, as slate evolves, any fossils are destroyed, so geologically, at least some of these Mosel rocks are in this intermediate shale-slate no-man's-land.

However, as the new minerals continue to form in this new alignment, the rock fissility will soon be supplanted, and if the material in this state were to be excavated, it would show a marked tendency to split in the direction of the new internal structure. This property is termed cleavage, and because the minerals are tightly aligned but are still small in size, the fracture can be outstandingly even and clean: We now have slate. Because of the changes that have taken place, it is regarded by geologists as a metamorphic rock. The newly formed minerals are referred to as metamorphic minerals, and these commonly include the newly generated micas and a green flaky mineral called chlorite. Various amounts of non-platy minerals such as quartz can also be present, remaining from the original silt in thin bands or among the aligned minerals, but because of their natural roundish shape, they don't contribute to the cleavage. Slate with considerable amounts of quartz will not split well. A quarryman (or a geologist) would call it a poor slate.

Slate is denser and stronger than shale, because of the more efficient packing of its minerals. But the defining difference is its property of cleaving into planar sheets, which in contrast to shale can be in any direction and has no relation to bedding. At the same time, the minerals responsible for the cleavage are too fine for us to see. This fineness means that without a microscope we can't discern why the slate is splitting—and this, as we shall learn shortly, is the key difference from schist.

Slate is, of course, one of the world's great roofing materials. In parts of Europe it rapidly replaced turf and thatch when the Industrial Revolution made it possible to extract and distribute slate rapidly and cheaply. Slates from North Wales, UK, for example, the Vermont–New York area of the USA, and around Fumay on the France–Belgium border can make beautiful roofs that will way outlast the very timbers and fixtures that hold the slates in place. (Incidentally, the word "tile" is properly used for a manufactured product, normally some sort of fired clay; the visual hallmark of many a European village is its roofs dominated either by dark slates or bright red tiles, according to whether slate or clay was available locally. "Shingle" is all-inclusive.)

Slate is found in a number of wine-producing areas around the world—for example, near Angers, just north of the River Loire in France; around Cebreros in the south of Castilla y León, Spain; in the Clare Valley, South Australia; the Aconcagua Valley of central Chile; and, apparently, the Huan Hills vineyards of Thailand. These slates are very varied in nature because, exactly in line with shales and their various parentages, slates can have all sorts of mineral compositions; a number of textbook slates around the world were originally volcanic ash.

Even so, the vast majority of slates were originally oceanic mud and now are some shade of gray in color, although, depending on their precise chemistry, there is a whole range of subtle hues. Slate colors have found their way into wine names, and in the quarrying trade they are given charming names like royal purple, sea green, and heather red. The Camel Valley vineyard in Cornwall, England, is located on a gray slate bedrock, which nearby is actively quarried for a whole range of slate products; Pant Du vineyard in North Wales uses as a mulch plum-colored slate waste from a quarry just a couple of kilometers away. In Valdeorras, northwest Spain, the spectacularly terraced vineyards above the River Sil have a distinctly slaty soil, and nearby the bedrock is quarried for the smooth, rather shiny, dark gray slates that are seen on roofs all over the world.

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Above: A dark gray slate vineyard at Domaine Piquemal, Espira de l'Agly, Roussillon.

Vine roots cannot take up the cleavable bonded aggregates of geological minerals that make slate what it is. In any case, slate lacks any smell or taste

Appearance, semblance, and reality

Is there something special about slate for wine? The belief is probably nowhere more embedded than in the vineyards alongside German rivers such as the Mosel and Rhine, and certainly any wine taster seeing those strikingly steep slopes and vines growing in what seems no more than slate rubble will be put in mind of expecting something distinctive. And the wines are, of course, just that—but the idea that the slate can actually be tasted in the wine, as some claim, has to be metaphorical. Vine roots cannot take up the cleavable bonded aggregates of geological minerals that make slate what it is, let alone somehow transmit them so that slate exists in the finished wine. In any case, like most rocks, slate lacks any smell or taste. To have a taste, a substance has to dissolve, and manifestly that is not the case with an inert material that makes practicable kitchen counters and such durable roofs. The current fashion in some restaurants to serve dishes on slate "plates" would lead to a different experience if the taste of the food was being affected!

The scientific evidence is that in cool, northern latitudes like Germany, the chief physical factors influencing the grapes are the climatic effects arising from the differing aspects and gradients of the hill slopes, and the proximity to a river. The main contribution of the slate soil itself, as with other kinds of vineyard geology, is its water properties, here allowing the free drainage so important in a moist climate. At the same time, the interlocking, jagged slate fragments give the soil a cohesion that helps reduce erosion on these remarkably steep slopes. Also, the dark colors of the slates contribute some warming effect and the smooth cleavage surfaces some light reflectivity, both possibly of significance in climates where grapes struggle to ripen. The chemistry appears relatively unimportant, in that most slates weather to yield the full range of nutrients required by vines (with a grower soon correcting any deficiencies that do arise).

There is, however, the intriguing matter of the reported differences in wines produced from vines growing near to each other but on soils of differently colored slate. For example, high in the empty and spectacular Cederberg Mountains of the Western Cape, South Africa, a difference is perceived between wines from Shiraz vines growing in red slate and from those nearby but in gray slate. Riesling wines from the blue slates of Wehlen, in the middle Mosel, Germany, are promoted as different to those from the red slates there. What could be causing this difference? The thermal properties of the soils presumably differ slightly, but this would hardly seem to be greatly significant, certainly in those parts of the world with an adequately warm climate. In other respects, the physical properties of the slates are identical; many a slab of slate shows different colors but is physically homogenous. And the obvious candidate of the chemical differences that are responsible for the colors doesn't really hold up.

The different gray colors of slates are due to variable amounts of carbon that is spread very finely through the rock. These variations can scarcely affect the vines, though, because the amounts are tiny—and of course, plants get their carbon from the atmosphere through photosynthesis. Other color variations depend on minute differences in trace elements such as titanium, vanadium, and chromium, again unlikely to affect vines, since the roots are barely able to take up these non-essential, potentially toxic elements, which in wine are in such minuscule amounts that they are not normally reported.

The chief color influence, certainly for red hues, is iron—not so much variations in the amount, which are small, but the extent to which it is in its so-called ferric form; it's this that gives the red color to many rocks and soils, such as the famous *terra rossa*. Ferric iron is insoluble and hence unusable directly by vines (and this can be a major problem with alkaline soils, which curb iron absorption and thus can lead to the iron deficiency known as chlorosis). But most slate soils, just as with shales, are on the acid side—some growers have to add lime to reduce this acidity—such that with all the clay minerals provided by weathered slate, malnutrition is rarely an issue. And clearly vines thrive nutritionally on red slates, absorbing the small amount of iron they need in its soluble, ferrous form, just as with other rocks, and with the presence of the ferric iron pigment having no detectable effect on their growth.

Naturally there may be some geological influence that is not being recognized, but I suspect the explanation probably lies not in subtle geological differences in the soil but in the factors that will be changing along with them, such as those to do with the mesoclimate and microbiology. These demonstrably affect vine growth and can vary on a surprisingly fine scale. However, unlike soil variations, they are not readily visible. They need patient data collection and, arguably, numerical data and microbiological taxa make for reading that is less attractive than some charismatic geology.

Anyway, to another question, a continuation of the one raised earlier: What happens if the slate isn't uplifted and exhumed but continues to be buried? Well, the ambient temperatures and burial pressures continue to increase, and they act to enhance the processes of forming new minerals, enabling them to grow to a larger size. If this material does eventually find itself at the Earth's surface, the minerals will have become big enough for us to see, and the platy ones will clearly show their alignment. But perhaps surprisingly, with these larger particles, this rock will no longer break as easily and cleanly as a slate. In other words, we now have a different kind of rock, one known by the ancient name of schist.

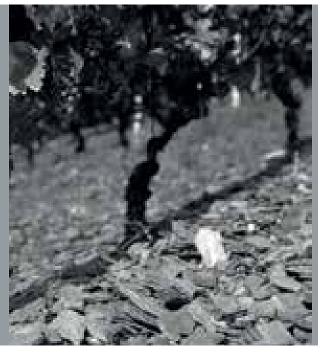
Schist: *"l'appelation nature, le grand terroir,"* etc

First, the gradational nature of the boundary between slate and schist. As mentioned above, with schist—unlike slate—we can see the aligned minerals, and the rock doesn't split with a clean cleavage. But these are subjective judgments. Different geologists will draw the line in different places, such that for one a vineyard may be sited on slate while another would call the rock a schist. Some workers interpose another rock name in here—phyllite—but this hardly solves the difficulty. An additional complication is that in other European languages the equivalent terms for these rocks have different ranges of meaning. For example, the German word *Schiefer* is commonly used for both slate and schist, as is the French word *schiste*, which is also sometimes extended to include shale. We, therefore, have to be careful when reading literature on slates and schists that is in English but derived from another language.

In English, a schist is defined by a more or less parallel alignment of minerals that are themselves clearly visible to the unaided eye. This arrangement in a rock is termed a "schistosity." Where the structure comprises aligned micas, the schist can almost gleam, since the silvery platelets make the schistosity reflect the sunlight. Just as with slate, various non-platy minerals can also be present, not only persisting grains of quartz but ones formed in the new metamorphic conditions, such as garnet, which commonly stands out from the schistosity as distinct pimples and lumps.

The blurry nature of the boundary between slate and schist is well illustrated in the Douro and in Priorat. For both areas, some accounts report a schist bedrock, while others call it slate. Again, neither is wrong. For the Douro vineyards, the important thing is that the planes of weakness in the rock, irrespective of whether we call it cleavage or schistosity, are very steeply inclined, allowing both rainwater percolation in wet times and penetration by vine roots. This contrasts with the other rock of the area, the massive granite that barely allows either effect. Much, though not all, of the Priorat area also happens to have planes of weakness in the bedrock that are steeply inclined or vertical.

Just as with its parent rocks, the word schist covers a range of mineral compositions and physical properties, including color. Those schists that are rich in mica minerals tend to be

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Above: (left) slate in Maury, Roussillon; (right) weathered shale in the Middle Rhine.

finely crumbly, whereas quartz-rich examples break into large tough slabs. Small amounts of graphite, from organic carbon in the original rock, give a dark gray or blue-black color, and green schists are common, because of the presence of newly formed green minerals such as chlorite. Sometimes the word greenstone is used for these rocks, and it pops up in some wine literature, but it has other geological meanings as well.

At Morgon in Beaujolais, the schist-derived, dull red soil is distinctly crumbly (the locals call it "rotted rock"), and at Cascastel-des-Corbières in the Languedoc, the tiny fragments of schist make a black vineyard soil that trickles between your fingers. In northern Corsica, by contrast, some of the schists are much richer in quartz, and the rock breaks into substantial pieces, some of which have been carried away from the fields to build houses. Much of the Dão DOC is a plateau of crumbly pink granite soils, but in the southwest of the region the bedrock is schist, with absurdly picturesque villages built largely of sheets of a silvery but rusty-weathering schist.

Although schist does not normally split as cleanly as a good slate, it can yield slabs for building, and it can make a handsome decorative stone. Nowhere has the rough splitting of schist been utilized more appealingly than along the western seaboard of southwest Scotland and Ireland, where sheets of the local dark-green schist were used in pre-medieval times for carving the iconic, pierced Celtic crosses that are replicated today on many a Christian gravestone and in jewelry.

In fact, although schist may seem a somewhat mysterious rock and its name curious (it may have the same origin as the word "schism"), it has been known and used for one thing or another since ancient times. For example, an Egyptian statue in the Louvre, Paris, dating from almost 4,000 years ago, is carved, at least according to the museum catalog, from schist. Damigero, writing in the 2nd century BC, recommended mixing *ischistos* with "women's milk" to counter "phantasms and hallucinations" and various other inscrutable complaints. And in AD 620, Isidore of Seville was remarking on how easily the rock called *schistos* breaks and how it gleams in the light—just like saffron, he thought.

Schist tends to occur in restricted zones, but they are scattered across the wine world. In addition to those already mentioned, examples include: the Minho and Alentejo regions of Portugal; Sonoma, California; Empedrado in the Maule region of Chile; Swartland, South Africa; and the Barossa Valley, Australia. In view of the disparity of such regions, coupled with the variability of the schist itself, it would seem that the current fashion for reporting that a wine is from "grapes grown on schist" cannot itself convey much about the wine. In France alone, for instance, schist occurs in such dissimilar places as Côte Rôtie, Savennières, Maury, Collioure, and Kastelberg in Alsace, and even within just one of these areas the schist can be very diverse.

Schist, schistose, and schistous

Nevertheless—and in contrast to slate, where, as we have seen, the belief is that a small variation in something like color causes a difference in the wines—the dominant thinking with schist is to emphasize a commonality. For example, publicity for Faugères in the Languedoc (from which the quotations heading the previous section come) says that the personality of its wines is due to the schist bedrock—even though the rock is highly variable and yields soils comprised of anything from crumbly shards, through slabs that can be used for building, to some far too acid for viticulture. Local growers even have various words for these various materials to reflect their differing characteristics for farming. (I find it hard to see how a distinctive trait to Faugères wines can be due, primarily at least, to such differing rocks and soils, but that is the assertion.)

There is an organized consortium of wine producers that maintains that all their wines are distinctive because their vineyards are located on schist. So far, this initiative includes, in addition to all the French places mentioned above, St-Chinian, Banyuls, Coteaux du Cap in the far north of Corsica, and Valais in Switzerland. Notwithstanding the disparity in physical conditions between these regions and the markedly different cultivars, styles of wine, viticultural and winemaking methods, and so on, a study for the consortium, L'Association Terroirs de Schistes, concluded that schist does give its members' wines a discernible character. What is this distinguishing hallmark? The report says that it's "a nice balance of freshness, nice acidity, supple and silky tannins," with "minerality and salinity being the most resilient feature." Hmm.

The variability of schist is also illustrated by the viticultural region with which in recent years it has perhaps become most closely associated: Central Otago, toward the south of South Island, New Zealand. Much of the material here is silvery gray, but it varies from being quartz-rich and strong and easily extracted in slabs for building purposes, to crumbly, delicate schists rich in mica. And while most of these were originally muddy sedimentary rocks, there are schists in the area that were originally volcanic ash and are distinctly green in color because of their chlorite content. So, once again, just like with the precursor shale and slate, although Central Otago wines are usually reported simply as "grown on schist", the phrase covers a multiplicity of rock compositions and properties.

Now for some fine semantics. In geology, the adjective for a rock showing a schistosity is "schistose." It's useful in helping describe rocks with differing degrees of particle alignment. But wine journalists have invented a new word: "schistous." It's usually used with reference to vineyard soils and seems to mean that they consist of fragments of schist. The word doesn't exist in the geological lexicon—but neither does an equivalent term. Although it may raise the eyebrows of some geologists, this new word is serving a useful, legitimate function for vineyard soils. Schistous nicely conveys a picture. By the same token, however, it is incorrect to describe a soil as schistose; a loose soil cannot possess a schistosity.

So, that is how schist comes about. But it's in no way the end of this saga of rock evolution. The Earth's processes grind on, so it is perfectly legitimate to ask again, What happens if the schist is not exhumed but is buried yet further? Our schists will have formed at temperatures around 300–500°C (570–930°F), at something like 15–20km (9–12 miles) below the ground, which to us sounds formidable. But from the planet's viewpoint we're still near the surface and well within the realm of processes that bury and exhume rocks. The rock is still way below its melting temperature, and the center of the Earth is another 6,000km (3,700 miles) away. Much more can happen to our schist, and the answer to the question is that further gradational changes will take place, going on to produce the material we call gneiss. But that's another story. ■